

**Computer system for electronic data processing**

The invention relates to a computer system for electronic data processing having a first data processing unit and a second data processing unit.

In addition to a central data processing unit in the form of a microprocessor, modern computer system frequently have a further data processing unit which is usually referred to as a coprocessor.

In contrast to the central data processing unit, which will be referred to below as a standard processor, a coprocessor is typically specialized for specific computational tasks.

Owing to its specialization for specific tasks, the coprocessor is typically able to execute certain computer program instructions faster than the standard processor.

What is understood here by faster execution of an instruction is that the instruction is executed by the coprocessor within fewer standard processor clock cycles than are required for its execution if the standard processor executes the instruction itself.

For example, many modern personal computers have a graphics card with a separate graphics coprocessor. Owing to its specialization for graphics calculations, said graphics coprocessor is able to execute computationally intensive graphics calculations, for example calculations of light effects in a 3D landscape, much faster than the standard processor of the personal computer.

A coprocessor specialized for specific tasks can thus be suitable for relieving the load on the standard

processor where applications have tasks for which the coprocessor is specialized.

The specialization of coprocessors results in less  
5 flexibility in comparison with the standard processor.  
Coprocessors are typically not capable of autonomously  
executing complete computer programs, but are supplied  
with instructions and with data required for executing  
said instructions by a standard processor. This means  
10 that the standard processor typically transfers to the  
coprocessor a data record containing a specification of  
the instruction to be executed itself plus a  
specification of the data required for executing the  
instruction.

15 For example, a standard processor transfers to an  
associated coprocessor a data record containing a bit  
code that specifies the instruction "Add two data  
elements", which data record additionally contains two  
20 memory addresses that address two memory cells of a  
computer data memory in which the data elements to be  
added are stored.

Said specification of the instruction and the  
25 specification of the data required for executing the  
instruction are referred to below as the instruction  
parameters of the instruction or as the (instruction)  
parameters required for an instruction.

30 The number of parameters required for different  
instructions varies. Likewise, the memory requirement  
for the parameters required for different instructions  
varies.

35 Many computer systems have for example a floating-point  
processor, that is to say a coprocessor which is  
specialized for performing floating-point operations.  
Such a coprocessor of a computer system is supplied by  
the standard processor of the computer system with

instructions for which few instruction parameters are required.

The reason for this is that the data processed during  
5 the operations associated with said instructions  
contains only individual floating-point values or small  
vectors with few (e.g. four) floating-point components.  
Consequently only a small amount of data is processed  
in the case of such instructions, which is why only a  
10 few parameters are required to specify this data. Owing  
to the low number of parameters required, the memory  
requirement for the parameters is also low.

As floating-point instructions can typically be  
15 specified using a few bits, likewise only few  
parameters with a low memory requirement are required  
to specify an instruction itself with which the  
floating-point processor is supplied.

20 This case, in which the parameters which have a low  
memory requirement for the instructions that are  
supplied to a coprocessor by a standard processor, for  
example because of the low number of parameters, will  
be referred to below as a tight coupling of the  
25 standard processor and the coprocessor.

With such a tight coupling, the coprocessor typically  
requires only few standard processor clock cycles for  
executing an instruction supplied to it by the standard  
30 processor.

In the case of a so-called loose coupling of a standard  
processor and a coprocessor, in each case a larger  
number of parameters with a higher memory requirement  
35 are required for the instructions that the standard  
processor supplies to the coprocessor than in the case  
of tight coupling of the two processors.

Loosely coupled processors as defined here process more

complex tasks than tightly coupled processors, for the processing of which tasks the loosely coupled processors typically require a large number of standard processor clock cycles.

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For example, graphics coprocessors execute instructions for which a large number of parameters are required. Up to 30 parameters may be required to specify the corners of a 3D object to be represented, the texture or the 10 lighting of the 3D object for example. A long period of time, that is to say many standard processor clock cycles, is required for executing complex graphics instructions. During the period of time in which the coprocessor is executing a graphics instruction, the 15 standard processor can execute other instructions.

In order for the coprocessor to be able to execute an instruction, the standard processor must transfer to the coprocessor the parameters required for the 20 instruction which specify the instruction itself plus the data required for executing the instruction.

Particularly in the case of a loose coupling of standard processor and coprocessor, owing to the high 25 memory requirement for the parameters to be transferred, this communication can entail a lengthy time requirement, that is to say a large number of standard processor clock cycles in which the standard processor is occupied with communication.

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The data processing of a standard processor and of an associated coprocessor, that is to say of a coprocessor which the standard processor supplies with instructions, is typically asynchronous. This means 35 that the coprocessor does not immediately commence executing an instruction transferred by the standard processor as soon as the data required is transmitted. For example, the standard processor can transfer the instruction parameters required for an instruction to

the coprocessor even while the latter is still executing another instruction.

This has the advantage, for example, that the standard  
5 processor does not have to wait until the coprocessor is ready for the transmission, but can transmit the parameters required for an instruction and subsequently immediately execute further instructions.

10 Owing to the asynchronous cooperation of standard processor and coprocessor, memories are required for the data transmission between standard processor and coprocessor, that is to say for the transfer of parameters required for instructions, since said data  
15 must be stored if it is not immediately processed by the coprocessor.

For the data transmission between a standard processor and a coprocessor, it is known to use a memory in which  
20 the standard processor can store data and from which the coprocessor can read data.

With this arrangement, the standard processor stores the parameters required for an instruction to be  
25 executed in the memory. The specification of the instruction itself and the specification of the data required for executing the instruction can be performed separately here, for example the coprocessor may have a special register and the standard processor stores the  
30 parameters that specify the data required for executing the instruction in the memory and requests the coprocessor to execute the instruction by storing the parameters that specify the instruction in the special register of the coprocessor.

35 Alternatively, the standard processor may store all instruction parameters required in the memory.

The coprocessor executes the instruction by accessing

the parameters stored in the memory or additionally in the special register.

This arrangement has the disadvantage that the standard  
5 processor must wait with storing the instruction parameters until the coprocessor no longer requires the instruction parameters previously stored in the memory. Otherwise the standard processor overwrites instruction parameters that are still required, which can lead to  
10 incorrect execution of one of the instructions executed by the coprocessor.

Since the coprocessor typically no longer requires the instruction parameters only once it has executed the  
15 respective instruction, the standard processor must wait with the transmission of instruction parameters required for an instruction until the coprocessor is not currently executing an instruction, that is to say in particular until the coprocessor has completed  
20 execution of the instruction preceding the instruction for which instruction parameters are to be transmitted.

Since in this case the standard processor cannot transfer any data to the coprocessor when the latter is  
25 executing an instruction, the end effect for processing an instruction is that the total of the time required for transferring the instruction parameters and the time required for the actual execution of the instruction by the coprocessor is required, since the  
30 coprocessor must initially wait for the transfer of the instruction parameters required for an instruction, cannot execute any other instruction during this time, and subsequently must execute the instruction.

35 In the prior art this disadvantage, as a result of which a significant advantage of the cooperation of standard processor and coprocessor is lost, is countered by the use of an alternate buffer or a first-in-first-out (FIFO) memory.

An alternate buffer has two memory regions. The standard processor of a computer system writes instruction parameters for example into the first 5 memory region of an alternate buffer. Once storing the instruction parameters has been completed, the coprocessor of the computer system can read out the instruction parameters from the first memory region and execute the respective instruction.

10

The standard processor does not need to wait until the coprocessor has completed execution of said first instruction, but can meanwhile store the instruction parameters required for a second instruction in the 15 second memory region. Once the standard processor has completed storing the instruction parameters required for the second instruction and the coprocessor has completed executing the first instruction, by accessing the second memory region of the alternate buffer, the 20 coprocessor can execute the second instruction while the standard processor writes the parameters required for a third instruction into the first memory region, and so forth.

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The use of a FIFO memory follows a similar principle. At one end of the FIFO memory the standard processor of a computer system stores the instruction parameters required for executing an instruction, while at the other end of the FIFO memory the coprocessor of the 30 computer system reads out the instruction parameters and executes the respective instructions.

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As a consequence, as with the use of an alternate buffer, it is possible for the data transfer from the standard processor to the coprocessor and the execution of instructions by the coprocessor to overlap.

Compared with the use of a simple memory, this enables a faster processing speed of the instructions to be

processed to be achieved.

However, the use of an alternate buffer or of a FIFO memory has the disadvantage that the instruction parameters of two successive instructions are written into two different memory regions. As a result, the standard processor must always write the entire instruction parameter set into the respective memory region, even if the instruction parameters of two successive instructions differ only very slightly.

In the field of software, and especially for the communication of program parts, it is customary to pass only changing parameters from one program part to another and not to pass parameters that remain constant a second time.

For example, the OpenGL graphics library operates as a "state machine". If, for example as a result of an OpenGL function call, the color is set to a specific value, for instance by the command

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glcolor3f(1.0,1.0,1.0);
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by means of which the color in which the objects are drawn is set to white, then all objects that are drawn by function calls following this command are drawn in white until the color in which objects are drawn is changed by a further glcolor command.

If a program that uses the OpenGL graphics library is executed on a typical conventional computer system having a graphics coprocessor, for example an IBM-compatible personal computer (PC) with a graphics card having a graphics processor, then all instruction parameters required for executing an instruction are always transferred. If the graphics coprocessor is to represent, for example, two white triangles on a screen, then the standard processor transfers to the

graphics processor two corresponding instructions with the respective instruction parameters, with the instruction parameters transferred for each of the two instructions containing the specification of the color  
5 as "white".

On the software level on the other hand it is sufficient to specify the color as "white" only once using a suitable function call.  
10

Since in the case of a computer system in which an alternate buffer or a FIFO memory according to the prior art is used for the data transmission from a standard processor to a coprocessor, all instruction  
15 parameters must always be transferred from the standard processor, even the ones that have not changed, the transmission of data between the standard processor and the coprocessor can require a considerable amount of time.  
20

Especially in the case of the loose coupling of processors, as described above, the transmission of a large number of instruction parameters with a high memory requirement is required for executing an  
25 instruction. Owing to the large volume of data, a high communications outlay is also necessary for transmission of this data. The standard processor stores the instruction parameters in a FIFO memory for example. If the volume of data is very high, the  
30 standard processor requires many clock cycles for the transmission.

This can have a considerable adverse affect on the processing performance of the computer system. For  
35 example, if the standard processor requires more time for transmitting the instruction parameters required for an instruction than the coprocessor requires for the execution of the instruction preceding said instruction, then the coprocessor is inactive until the

transmission is completed. The processing performance of the computer system is thus less than it theoretically could be, that is if both processors were continuously executing instructions.

5

While the standard processor is transmitting data to the coprocessor, the processing performance of the standard processor available for executing other instructions is limited. In particular when a large 10 volume of data is to be transmitted, it is consequently of great importance for the processing performance of the computer system that the data is transmitted efficiently.

15 In extreme cases, the standard processor requires even longer for the transmission of the parameters required for an instruction than the standard processor requires for executing the instruction. In this case it is actually more efficient, that is to say less time is 20 required for processing the instruction, if the standard processor does not pass the instruction on to the coprocessor but executes it itself.

Publication [1] discloses an architecture for a 25 computer system having a main processor and a graphics processor. In this arrangement the main processor can store graphics commands in a main memory. The graphics processor can read said commands out of the main memory, wherein the graphics commands can be buffered 30 by means of a FIFO buffer arranged between the main memory and the graphics processor.

In [2] a processor is disclosed which has an intermediate memory (cache). The intermediate memory is 35 connected to a coprocessor and the coprocessor can store results in the intermediate memory.

Publication [3] discloses a graphics accelerator having a local memory, a coprocessor and a DMA (Direct Memory

Access) unit which is used for data transmission between the local memory and an external memory.

5       The object of the invention is to provide a device for data transmission from a first data processing unit to a second data processing unit in which the data transmission is more efficient than that of the prior art.

10      In this context "more efficient" means that the standard processor uses on average fewer clock cycles to transmit data to be transmitted to the coprocessor than are used for data transmission from a standard processor to a coprocessor according to the prior art.

15      The object is achieved by a computer system for electronic data processing as claimed in the independent claim.

20      Preferred developments of the invention emerge from the dependent claims.

A computer system for electronic data processing is provided which has a first data processing unit, a  
25     second data processing unit and a data transmission memory device, wherein the data transmission memory device is connected on the input side to the first data processing unit and on the output side to the second data processing unit, and which data transmission  
30     memory device is set up to transmit data records from the first data processing unit to the second data processing unit, and wherein the data transmission memory device has a first memory region and a second memory region, wherein the first memory region and the  
35     second memory region are set up to store one data record in each case, and wherein the data transmission memory device is set up in such a way that the transmission of a data record to be transmitted from the first data processing unit to the second data

- processing unit is performed in accordance with the following steps: transferring to the first memory region and storing in the first memory region the data contained in the data record to be transmitted; copying  
5 the data record stored in the first memory region into the second memory region if copying is released; transferring the data record stored in the second memory region to the second data processing unit.
- 10 Since the data transmission memory device used according to the invention for the data transmission between the first data processing unit, which is preferably a standard processor, and the second data processing unit, which is preferably a coprocessor, has  
15 two memory regions, it is possible for the first data processing unit to perform a write access to the first memory region while the second data processing unit is accessing the second memory region.
- 20 In a preferred embodiment, the first data processing unit is a standard processor and the second data processing unit is a coprocessor.
- In the preferred embodiment in which the first data  
25 processing unit is a standard processor and the second data processing unit is a coprocessor, this means in particular that the standard processor can write instruction parameters required for an instruction into the first memory region while the coprocessor is still  
30 executing an instruction preceding the instruction and is accessing the instruction parameters required for the preceding instruction which are stored in the second memory region.
- 35 As a consequence, it is possible in the computer system for the data transfer from the standard processor of the computer system to the coprocessor of the computer system and the execution of instructions by the coprocessor to overlap.

This has the advantage, for example, that the standard processor does not have to wait until the coprocessor is ready for the transmission of data, but can write  
5 the parameters required for an instruction into the first memory region and subsequently immediately process further tasks.

There is therefore an efficiency advantage conferred by  
10 the data transmission between the standard processor and the coprocessor in the computer system in comparison with a computer system which does not permit overlapping of the data transfer from the standard processor to the coprocessor and the execution of  
15 instructions by the coprocessor.

Moreover, with the computer system it is not always necessary to transmit a complete data record if data that it contains has already been previously  
20 transmitted, provided that said data is still contained in the data record stored in the first memory region.

In the preferred embodiment in which the first data processing unit is a standard processor and the second data processing unit is a coprocessor, this means in particular that the standard processor need only transfer to the first memory region the instruction parameters required for an instruction which differ from the instruction parameters required for the  
30 instruction preceding the instruction.

If, for example, two instructions whose instruction parameters required differ only slightly in each case are to be successively executed by the coprocessor, the  
35 standard processor need transfer to the first memory region the complete instruction parameter set only for the instruction to be executed first, and for the instruction to be executed second need only transmit to the first memory region the instruction parameters

which differ from the instruction parameters required for the first instruction.

The computer system thus confers a considerable  
5 efficiency advantage over a computer system in which an alternate buffer or a FIFO memory is used, as in this case, as described above, the complete instruction parameter set must always be transmitted from the standard processor to the alternate buffer or to the  
10 FIFO memory, and consequently the volume of data to be transmitted is greater than with the computer system described above.

In one embodiment, the first data processing unit does  
15 not transmit the instruction parameters required for a single (program) instruction to the second data processing unit, but rather the instruction parameters required for a plurality of instructions are transmitted during a transmission operation to the  
20 second data processing unit, which executes the plurality of program instructions once the transmission has been completed.

This exemplary embodiment corresponds to a loose  
25 coupling of the first data processing unit and the second data processing unit. Since in this case a large volume of data is to be transmitted, efficient data transmission is particularly important.

30 In a further embodiment, the data transmission memory device has a special memory, a so-called parameter memory (parameter RAM), by means of which the copying of a data record from the first memory region into the second memory region can be executed in one clock  
35 cycle. Since during the copying operation it is neither possible for the standard processor to write to the first memory region nor for the coprocessor to execute an instruction, this embodiment is preferred.

For example, the information as to whether the second data processing unit is ready for data transmission is transferred to the data transmission memory device and, based on the information as to whether the second data 5 processing unit is ready for data transmission, the decision is made as to whether copying is released.

With the computer system provided, it is further preferred if copying is released if no data is 10 transferred from the second memory region to the second data processing unit.

With the computer system provided it is further preferred if, in the step of transferring to the first 15 memory region and storing in the first memory region the data contained in the data record to be transmitted, only data which is not contained in the data record stored in the first memory region is transmitted.

20 In the computer system provided, it is further preferred if the first data processing unit is a standard processor and the second data processing unit is a coprocessor, and the data to be transmitted by 25 means of the data transmission memory device is required for the execution of a program instruction by the coprocessor.

According to one embodiment of the computer system 30 provided, the first memory region is a first memory bank and the second memory region is a second memory bank, and data can be transmitted from the first memory bank into the second memory bank by means of a transfer bus.

35 According to one embodiment of the computer system provided, the first data processing unit is connected by means of a system bus to the first memory bank, and the above-mentioned transfer bus has a greater

bandwidth than the system bus.

In the computer system provided, it is preferred if the data transmission memory device has a plurality of  
5 memory cells having a first memory element and a second memory element in each case, wherein each memory element is set up to store a single bit and wherein, when the data record stored in the first memory region is copied into the second memory region, the bit stored  
10 in the respective first memory element of a memory cell is copied into the respective second memory element of the memory cell.

In the computer system provided, it is further  
15 preferred if both memory regions are situated on one memory chip.

In the computer system provided, the coprocessor may be  
a graphics, image processing or mathematical  
20 coprocessor.

Exemplary embodiments of the invention are represented in the figures and are described in greater detail below.

25 Figure 1 shows a computer system according to a first exemplary embodiment of the invention;

Figure 2 shows a computer system according to a second exemplary embodiment of the invention;

30 Figure 3 shows a flowchart of the processing of an instruction by means of the computer system shown in Figure 2;

35 Figure 4 shows a computer system according to a third exemplary embodiment of the invention which has a parameter memory;

Figure 5 shows the structure of the parameter memory from Figure 4;

5       Figure 6 shows the structure of a memory cell of the parameter memory from Figure 4.

**Fig. 1** shows a computer system 100 according to a first exemplary embodiment of the invention.

10      The computer system 100 has a standard processor 101, a computer bus 102 and a memory 103.

15      The standard processor 101 is connected by means of the computer bus 102 to the memory 103 and accesses the memory 103 by means of the computer bus 102. The memory 103 contains instructions 110 of a computer program and data 111 required for executing the instructions. When the computer program stored in the memory 103 is executed, the program instructions 110 are transferred  
20      to the standard processor 101 by means of the computer bus 102. The standard processor either executes a program instruction transferred from the memory 103 itself, or it decides, based on the characteristics of the program instruction, that a coprocessor 104 should  
25      execute the instruction.

30      For example, the program instruction currently to be processed is an instruction for displaying a triangle on a screen 105 and the coprocessor 104 is a graphics coprocessor. In this example the standard processor 101 decides that the graphics coprocessor 104 should execute the instruction.

The reason for this decision may be

35      - that the coprocessor 104 is a processor specialized for program instructions of the type of program instruction to be processed and can therefore execute the program instruction faster than the standard processor 101,

- that the standard processor 101 is not suitable for executing the program instruction because it does not have the required instruction set available, or
- 5       - that although the standard processor 101 can execute the instruction as fast as or faster than the coprocessor 104, it nevertheless passes it to the coprocessor 104 for execution to relieve the load on the standard processor 101.

If the standard processor 101 decides that the coprocessor 104 should execute a particular program instruction, then the parameters required for executing 15 the instruction are transferred by means of a data transmission memory device 106.

The parameters required for executing an instruction are all information that the coprocessor 104 requires 20 to execute the instruction. Typically this is a specification of the instruction itself plus a specification of the data elements required during execution of the instruction, or other information such as a memory address at which the result of the 25 instruction is to be stored for example.

For example, the parameters required for executing an instruction have a data word containing the instruction "Add the two data elements located at a first address 30 and a second address in the memory and store the result at a memory location in the memory specified by a third address".

In addition to this specification of the instruction to 35 be executed itself, in this case the parameters required for executing the instruction have the first address and second address that specify the data elements required for executing the instruction, namely the memory addresses that indicate where the data

elements are stored in the memory.

In this example, the parameters required for executing  
the instruction also have the address indicating the  
5 memory location at which the result of the addition is  
to be stored.

The parameters required for executing an instruction  
will now be referred to below simply as "instruction  
10 parameters".

Embodiments of the data transmission memory device 106  
and an embodiment of the sequence of transfer of the  
instruction parameters required for an instruction from  
15 a standard processor to a coprocessor by means of an  
embodiment of the data transmission memory device will  
be described further below.

Like the standard processor 101, the coprocessor 104 is  
20 also connected to the computer bus 102. If the  
coprocessor 104 is, for example, a graphics coprocessor  
connected to the screen 105, control signals that  
control the screen 105 in such a way that the screen  
105 displays a desired graphical representation, for  
25 example a triangle, may be transferred from the  
coprocessor 104 to the screen 105.

In addition, the coupling of the standard processor 101  
and the coprocessor 104 by means of the computer bus  
30 102 enables the transmission of signals between the  
standard processor 101 and the coprocessor 104.

In one embodiment, the coprocessor 104 transfers for  
example a signal containing the information that the  
35 coprocessor 104 has completed a specific instruction to  
the standard processor 101.

For example, the coprocessor 104 has executed a  
calculation instruction and stored the result of the

execution of the calculation instruction at a memory address specified for the parameters required for executing the instruction in the memory 103. Once the coprocessor 104 has signaled completion of the 5 execution of the calculation instruction to the standard processor 101 by means of the computer bus 102, it can access the result stored in the memory 103.

In one embodiment, the instruction parameters required 10 for executing an instruction are not all transmitted by means of the data transmission memory device 106.

For example, the instruction parameters that specify the instruction itself are transmitted by means of the 15 computer bus 102 and stored in a local instruction memory of the coprocessor 102.

It is however preferred that the majority of instruction parameters are transmitted by means of the 20 data transmission memory device 106.

The computer system 100 has additional conventional devices. In this embodiment, a digital versatile disk (DVD) drive 107, a keyboard 108 and a computer mouse 25 109 are connected to the computer bus 102.

**Fig. 2** shows a computer system 200 according to a second exemplary embodiment of the invention.

30 The computer system 200 has a standard processor 201 and a coprocessor 202.

The computer system according to this exemplary embodiment has a plurality of devices that serve for 35 communication between the standard processor 201 and the coprocessor 202: a first memory bank (master bank) 205, a second memory bank (slave bank) 206 and a control device 207.

The control device 207 has an interface control device 208 and a memory control device 209.

In this embodiment, the interface control device 208  
5 and the memory control device 209 are not separate devices, but together form the control device 207.

In this embodiment the master bank 205 and the slave bank 206 are conventional dual port memory modules,  
10 that is to say memory modules having two ports in each case by means of which read and/or write access to the memory modules is possible.

The computer system 200 further has a plurality of  
15 computer buses: a system bus 202, a transfer bus 203 and a coprocessor bus 204.

The system bus 202 connects the master bank 205, the standard processor 201, the control device 207 and  
20 other devices, not represented, such as a computer memory and input and output devices.

The transfer bus 203 enables data transmission from the master bank 205 to the slave bank 206.  
25

The coprocessor bus 204 enables the coprocessor 202 to access the slave bank 206.

In this embodiment, the master bank 205, the slave bank 206 and the memory control device 209, which is  
30 designed together with the interface device 208 in the form of the control device 207, and the transfer bus 203 form the data transmission memory device 210 according to the invention which is represented in  
35 Fig. 2 by the dotted rectangle.

The standard processor 201 and the coprocessor 202 can communicate with each other on a first data transmission path by means of the system bus 202, the

master bank 205, the transfer bus 203, the slave bank 206 and the coprocessor bus 204, and on a second data transmission path by means of the system bus 202 and the control device 207.

5

However, the transfer bus 203 enables only data transmission from the master bank 205 to the slave bank 206 and not vice versa.

10 The sequence of data transmission between the standard processor 201 and the coprocessor 202, specifically the instruction parameters required for an instruction, will be explained below with reference to Fig. 2 and Fig. 3.

15

**Fig. 3** shows a flowchart 300 of the processing of an instruction by means of the computer system shown in Fig. 2.

20 In step 301 the standard processor 201 receives a program instruction of a computer program being processed by the computer system 200. The standard processor 201 receives said program instruction for example by accessing a program memory, not shown in  
25 Fig. 2, by means of the system bus 202.

In step 302 the standard processor 201 decides, based on the type of program instruction, whether the standard processor itself or the coprocessor 202 should execute the instruction.  
30

In this example it is assumed that it is decided that the coprocessor 202 should execute the (program) instruction.

35

In this example it is further assumed for the better understanding of the invention that the current instruction, that is to say the program instruction received from the standard processor 201 in step 301,

is not the first instruction of the computer program processed by the computer system 200 where it is decided that it should be executed by the coprocessor 202.

5

In particular it is assumed that the instruction parameters required for an instruction preceding the current instruction have been transferred to the coprocessor 202 by means of the master bank 205 and the  
10 slave bank 206.

In step 303 the standard processor 201 determines the instruction parameters required for executing the instruction.

15

It can determine this for example by accessing a memory, not shown in Fig. 2.

20

In step 304 the standard processor 201 transfers the instruction parameters by means of the system bus 202 to the master bank 205 in which the instruction parameters are stored.

25

According to the invention, only the changed instruction parameters are transferred and stored here, that is to say the instruction parameters that differ from the parameters required for the preceding instruction executed by the coprocessor 202.

30      35

According to the invention, following their transfer to the coprocessor 202 by means of the master bank 205 and the slave bank 206, the instruction parameters required for the preceding instruction are not deleted. Said instruction parameters are thus still stored in the master bank 205 at the beginning of step 304. In step 304 the standard processor transfers to the master bank 205 only the instruction parameters required for the current instruction which differ from the parameters required for the preceding instruction.

In one embodiment, the standard processor 201 itself checks which instruction parameters differ from the instruction parameters stored in the master bank 205.

5

For example, the computer program can be executed using a hardware driver which is set up to control the standard processor 201 in such a way that it checks which instruction parameters differ from the  
10 instruction parameters stored in the master bank 205.

Once the instruction parameters have been transferred, the standard processor 201 transfers the information that it has completed the transfer of a set of  
15 instruction parameters for an instruction to the control device 207.

In step 305 the interface control device 208 of the control device 207 checks whether the coprocessor 202  
20 is ready to execute a new instruction.

In this manner it is checked in particular whether the coprocessor 202 is accessing the slave bank 206 by means of the coprocessor bus 204.

25

The sequence does not continue with the next step 306 until the information that the coprocessor 202 is ready is present.

30 In step 306 the data stored in the master bank 205 is transmitted into the slave bank 206 by means of the transfer bus 203.

35 The memory control device 209 of the control device 207 receives from the interface control device 208 of the control device 207 the information that the coprocessor 202 is ready, as tested in step 305.

Since the coprocessor 202 therefore no longer requires

the data stored in the slave bank 206, because it has completed executing the last instruction, the data can be overwritten.

- 5 The memory control device 209 of the control device 207 controls the copying operation of the data from the master bank 205 into the slave bank 206.

It is preferred if the transfer bus 203 has a wide  
10 bandwidth because in this case the copying operation can be executed in a few transfer bus clock cycles. This is advantageous because, during data transmission from the master bank 205 to the slave bank 206 by means of the transfer bus 203, neither the standard processor  
15 201 can access the master bank 205, nor can the coprocessor 202 access the slave bank 206, that is to say in particular the coprocessor 202 cannot execute any instruction during the copying operation.

20 If, for example, 32 instruction parameters are required, with each of the parameters having a memory requirement of 32 bits, and if the transfer bus 203 has a bandwidth of 256 bits, then the instruction parameters can be transmitted in 4 clock cycles.

25

It is preferred if the transfer bus 203 has a bandwidth that is at least five times greater than the system bus 202.

30 The bandwidth of the transfer bus 203 can be increased, for example by increasing the transfer bus clock rate or by increasing the number of data lines of the transfer bus 203.

35 Once the copying operation of the data from the master bank 205 into the slave bank 206 has been completed, the memory control device 209 of the control device 207 signals that the copying operation has been completed to the interface control device 208 of the control

device 207.

The data contained in the master bank 205 is retained once the copying operation has been completed.

5

In step 307 the interface control device 208 of the control device 207 signals to the coprocessor 202 that it should commence executing the instruction.

10 The coprocessor 202 then executes the instruction, obtaining the instruction parameters required for this by accessing the slave bank 206.

15 In one embodiment, the instruction parameters required for executing an instruction are not all transmitted by means of the master bank 205 and the slave bank 206.

20 For example, the instruction parameters that specify the instruction itself are transmitted by means of the interface control device 208 of the control device 207 to the coprocessor 202.

25 **Fig. 4** shows a computer system 400 according to a third exemplary embodiment of the invention which has a parameter memory.

The computer system 400 has a standard processor 401 and a coprocessor 402.

30 The computer system 400 further has an interface control device 403 and a parameter memory (parameter RAM) 404 which is described in detail further below.

35 The parameter memory 404 has a first memory region 407 and a second memory region 408.

The parameter memory 404 may be designed in the form of a single memory chip.

The computer system 400 further has a system bus 405 and a coprocessor bus 406.

5       The system bus 405 connects the standard processor 401, the parameter memory 404, the interface control device 403 and further devices, not shown, of the computer system 400, for example a computer memory and input and output devices.

10      The coprocessor bus 406 connects the coprocessor 402 to the parameter memory 404.

15      The parameter memory 404 corresponds to the data transmission memory device according to the invention.

In contrast to the computer system 200 shown in Fig. 2, the computer system 400 has no memory control device 209.

20      The sequence of processing a computer program by means of the computer system 400 is analogous to the sequence of processing a computer program by means of the computer system 200 described with reference to Fig. 2 and Fig. 3.

25      The first memory region 407 corresponds to the master bank 205 and the second memory region 408 corresponds to the slave bank 206.

30      One difference between the sequence of processing a computer program by means of the computer system 400 and the sequence of processing a computer program by means of the computer system 200 is that the computer system 400 has no memory control device 209 that controls the copying operation between the first memory region 407 and the second memory region 408.

The sequence of controlling the copying of the instruction parameters from the first memory region 407

into the second memory region 408 will become clear from the description of the parameter memory 404 below.

5      **Fig. 5** shows the structure of the parameter memory 500 from Fig. 4.

The parameter memory 500 has a plurality of memory cells, of which twelve memory cells 501 to 512 are represented.

10     In this embodiment, the memory cells 501 to 512 are arranged in the form of a two-dimensional matrix having a plurality of (memory cell) rows and (memory cell) columns.

15     Each of the memory cells 501 to 512 is connected to a write amplifier 513, a read amplifier 514, a write address decoder 515, a read address decoder 516 and a transfer control signal line 517.

20     If write data 518 is to be written into the parameter memory 500, it is fed into the write amplifier 513 in the form of data words.

25     In this embodiment the data word has as many data bits as the parameter memory 500 has memory cell columns.

30     The data word is fed into the write amplifier 513 in the form of an electrical signal. Said electrical signal is electrically amplified by the write amplifier 513.

35     The write amplifier 513 has as many outputs as the data word has data bits. Each output of the write amplifier 513 corresponds to one data bit of the data word, and the data bit corresponding to an output is output to said output by the write amplifier 513.

A write address 519 specifies the row with memory cells

of the parameter memory in which the data word 518 is to be stored. The write address 519 is fed into the write address decoder 515, which has an output for each of the memory cell rows of the parameter memory 500,  
5 and at the output corresponding to the memory cell row addressed by the write address 519, the write address decoder 515 outputs a binary one, and outputs a binary zero at the other outputs.

10 The operation during writing into the memory cells 501 to 512 will be described further below with reference to Fig. 6.

15 If data is to be read out of the parameter memory 500, a read address 520 that specifies the memory cell row of the parameter memory 500 from which data is to be read is fed into the read address decoder 516.

20 The read address 515 has an output for each of the memory cell rows of the parameter memory 500, and at the output corresponding to the memory cell row addressed by the read address 520, the read address decoder 515 outputs a binary one, and outputs a binary zero at the other outputs.

25 The memory cells of the memory cell row specified by the read address 520 then each output a data bit that is stored therein.

30 The exact functioning of the memory cells 501 to 512 will be described further below with reference to Fig. 6.

35 The data bits output from the memory cells of the memory cell row specified by the read address 520 are fed into the inputs of the read amplifier 514, the number of inputs of which is equal to the number of memory cell columns of the parameter memory 500.

The data bits are fed into the read amplifier 514 in the form of electrical signals and are amplified there and output as read data 521 in the form of data words.

5 By means of the transfer control signal line 517, a transfer control signal 522 can be fed into the memory cells 501 to 512 in the form of a single transfer control signal bit.

10 If the transfer control signal bit has the value binary one, then the copying operation according to the invention from the first memory region 407 into the second memory region 408 of the parameter memory 404 is executed.

15

This will be explained below with reference to Fig. 6.

20 **Fig. 6** shows the structure of one memory cell 600 of the memory cells 501 to 512 of the parameter memory 404 from Fig. 4.

The memory cell 600 has a first memory element (master latch) 601 and a second memory element (slave latch) 602.

25

Both memory elements 601, 602 are set up to store a single bit in each case.

30 The two memory elements 601, 602 further always output the value of the respective bit stored therein.

35 The totality of the first memory elements of the memory cells 501 to 512 of the parameter memory 404 form the first memory region 407 and the totality of the second memory elements of the memory cells 501 to 512 of the parameter memory 404 form the second memory region 408.

The memory cell 600 is connected by means of a write bit line 603 to the write amplifier 513, by means of a

write word line 604 to the write address decoder 515, by means of a read bit line 605 to the read amplifier 514, and by means of a read word line 606 to the read address decoder 516.

5

A transfer signal 607 can further be fed into the second memory element 602.

10 The transfer signal 607 corresponds to the transfer control signal 522 described above and fed into the memory cells 501 to 512 by means of the transfer control signal line 517.

15 The transfer signal 607 accordingly has only a single bit.

The first memory element 601 has a control input 609 and the second memory element 602 has a control input 610.

20

If no transfer signal 607 is transmitted, the value zero is present at the control input 610.

25 The first memory element 601 has a data input 611 and the second memory element 602 has a data input 612.

30 If a bit having the value one is present at the control input 609, then the first memory element 601 stores the bit present at the data input 611 and the bit previously stored in the first memory element 601 is overwritten. If a bit having the value zero is present at the control input 609, then the bit stored in the first memory element 601 is retained and not overwritten by the bit present at the data input 611.

35

If a bit having the value one is present at the control input 610, then the second memory element 602 stores the bit present at the data input 612 and the bit previously stored in the second memory element 602 is

overwritten. If a bit having the value zero is present at the control input 610, then the bit stored in the second memory element 602 is retained and not overwritten by the bit present at the data input 612.

5

As described above, in the case of a write access a data bit is transmitted from the write amplifier 513 by means of the write bit line 603.

10 If the memory cell 600 is in the row of the parameter memory 500 specified by the write address 519, then, as described above, a bit having the value one is transferred by means of the write word line 604 from the write address decoder 515 to the first memory  
15 element 601.

In this case a bit having the value one is present at the control input 609. The first memory element 601 therefore stores the data bit present at the data input  
20 611 which was transferred by means of the write bit line 603.

If the memory cell 600 is not in the row of the parameter memory 500 specified by the write address  
25 519, then, as described above, a bit having the value zero is transferred by means of the write word line 604 from the write address decoder 515 to the first memory element 601.

30 In this case a bit having the value zero is present at the control input 609. The first memory element 601 therefore does not store the data bit present at the data input 611 which was transferred by means of the write bit line 603.

35

Analogously to the processing of an instruction by means of the computer system 200 shown in Fig. 2 which was described with reference to Fig. 3, during processing of an instruction by means of the computer

system 400 having a parameter memory 404 as illustrated by Fig. 5 and Fig. 6, the parameters required for the instruction are transmitted to the data transmission memory device, which corresponds to the parameter 5 memory 404 in the computer system 400 shown in Fig. 4, and are stored there.

Once said transmission and storage operation in the 10 computer system 400 has been completed, the interface device 403 checks whether the coprocessor 402 is still accessing data stored in the second memory region 408 or is ready for the execution of the instruction and the copying operation of the data of the first memory region 407 into the second memory region 408.

15 If the coprocessor 402 is ready, a transfer signal 607 is sent by means of the interface device 403 to the parameter memory 404, which signal activates the copying operation of the data of the first memory 20 region 407 into the second memory region 408 in the manner described below.

The transfer signal 607 is a signal having a bit with 25 the value one. Said bit having the value one is present at the control input 610 of the second memory element 602. As a consequence, the value stored in the first memory element 601 which is present at the data input 612 is stored in the second memory element 602.

30 The transfer of a transfer signal 607, which is a signal having a bit with the value one, thus activates the copying of the data stored in the first memory region 407 into the second memory region 408.  
35 According to this preferred embodiment, only one clock cycle is required for the copying operation.

Once the copying operation is complete, analogously to the processing described with reference to Fig. 3, a

signal is transferred to the coprocessor 402 by means of the interface control device 403, which signal instructs the coprocessor 402 to execute the instruction using the data stored in the second memory region 408.

This mode of functioning of the memory cell 600 during a read access of the coprocessor 402 to the second memory region 408 will be described below.

10

If the memory cell 600 is in the row of the parameter memory 500 specified by the read address 520, then, as described above, a bit having the value one is transferred by means of the read word line 604 from the 15 read address decoder 515 to a tri-state driver 608.

In this case the value one is present at the control input of the tri-state driver 608. The tri-state driver 608 thus outputs the value present at its data input, 20 that is to say the value of the bit stored in the second memory element 602.

If the memory cell 600 is not in the row of the parameter memory 500 specified by the read address 520, 25 then, as described above, a bit having the value zero is transferred by means of the read word line 604 from the read address decoder 515 to the tri-state driver 608.

30 In this case the value zero is present at the control input of the tri-state driver 608. The tri-state driver thus assumes a high-resistance output state.

During a read access, the read bit line 605 therefore 35 has the value that is stored in the second memory element 602 of the memory cell 600 corresponding to the read bit line 605 in the memory cell row addressed by the read address 520.

In this embodiment, the coupling of the first memory element 601 and the second memory element 602 within the memory cell 600 replaces a transfer bus such as the computer system 200 shown in Figure 2 has for example.

5

By means of this local, direct one-to-one coupling of the first memory element 601 and the second memory element 602 within a memory cell, the data is transmitted from the first memory region 407 into the 10 second memory region 408 locally within the memory cell 600.

The memory cell 600 thus has a local transfer bus, with the result that a further transfer bus between the 15 first memory region 407 and the second memory region 408 is not required, and in particular the copying operation between the first memory region 407 and the second memory region 408 can be performed in one clock cycle.

20

The following publications are cited in this document:

[1] US 6 411 301 B1

5 [2] US 2003/0222877 A1

[3] US 6 501 480 B1

**List of reference numerals**

	100	Computer system
	101	Standard processor
5	102	Computer bus
	103	Memory
	104	Coprocessor
	105	Screen
	106	Data transmission memory device
10	107	DVD drive
	108	Keyboard
	109	Mouse
	110	Instructions
	111	Data
15	200	Computer system
	201	Standard processor
	202	System bus
	203	Transfer bus
	204	Coprocessor bus
20	205	Master bank
	206	Slave bank
	207	Control device
	208	Interface control device
	209	Memory control device
25	210	Data transmission memory device
	300	Flowchart
	301-307	Processing steps
	400	Computer system
	401	Standard processor
30	402	Coprocessor
	403	Interface control device
	404	Parameter memory
	405	System bus
	406	Coprocessor bus
35	407	First memory region
	408	Second memory region
	500	Parameter memory
	501-512	Memory cells
	513	Write amplifier

514	Read amplifier
515	Write address decoder
516	Read address decoder
517	Transfer control signal line
5 518	Write data
519	Write address
520	Read address
521	Read data
522	Transfer control signal
10 600	Memory cell
601	First memory element
602	Second memory element
603	Write bit line
604	Write word line
15 605	Read bit line
606	Read word line
607	Transfer signal
608	AND gate
609	Control input
20 610	Control input
611	Data input
612	Data input